

Which Insulating Oil Analytical Tests to Request and When

Transformer oil testing laboratories receive hundreds of thousands of samples per year for analysis. Some samples only require one test, such as Polychlorinated (PCB) content or dissolved gas-in-oil analysis (DGA). Other samples require a multitude of tests. Choosing the correct tests to perform in a given circumstance can be a daunting task.

Testing is of increasing importance today as new and better tests become available. This is especially true in the utility and industrial environments where out-of-service testing of apparatus is becoming less frequent. The in-service testing, primarily performed on easily sampled electrical insulating liquids, can help assess the condition of the insulating materials and, more importantly, serve as diagnostic procedures to detect and identify incipient faults in apparatus. In addition, some of these same tests can be used to verify that a failure has occurred and then to aid in the identification of the cause of failure. Advances in testing have provided some tools to help estimate the condition of the solid insulation, which is often a difficult task. Some tests can be performed to help decide which remedial actions might be most effective, such as reclamation or reconditioning of the oil. Finally, testing also provides a means to check the condition of oil in storage, whether it be new or used, to determine if it complies with specifications such as ASTM D3487, IEC 60296, IEEE C57.106, or company specifications.

This article attempts to provide some basic information to users of testing laboratories so they can select the right tests to diagnose the condition of the solid and liquid insulation in electric apparatus. Oil testing is not limited to samples from transformers but also includes bulk transports, drums, and other electrical apparatus. Sampling and testing can also help to determine:

- if accidental mixing of different dielectric liquids has taken place.
- if the method of transportation contaminated the dielectric liquid.
- if the handling equipment to transfer the dielectric liquid contaminated the product.



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Some of the situations discussed in which specific analytical tests are employed include:

- Qualification of a refiner and large bulk shipments of oil.
- Small shipments of new oil and new oil shipped in large power transformers.
- Shipments of new oil in drums and small distribution transformers.
- Base line tests for power and distribution transformers.
- Tests to perform on in-service oil.

TABLE 1
Tests to Qualify a Product

TEST	ASTM METHOD	TEST	ASTM METHOD
Aniline Point	D 611	Oxidation Stability	D 2440
Carbon Type Composition	D 2140	Polychlorinated Biphenyls (PCBs)	D 4059
Color	D 1500	Pour Point	D 97
Corrosive Sulfur	D 1275	Power Factor at 25°C	D 924
Dielectric Breakdown	D 877	Power Factor at 100°C	D 924
Dielectric Breakdown	D 1816	Power Factor Valued Oxidation	Doble
Flash Point	D 92	Relative Density 60/60	D 1298
Furanic Compounds	D 5837	Rotating Bomb	D 2112
Gassing Tendency at 80°C	D 2300	Sludge-Free Life	Doble
Impulse Breakdown Voltage	D 3300	Viscosity at 40°C	D 445
Interfacial Tension	D 971	Visual Examination	D 1524
Neutralization Number	D 974	Water Content	D 1533
Oxidation Inhibitor Content	D 2668		

TABLE 2
Tests on a Large Shipments of New Oil (Two or More Tankers)

TEST	ASTM METHOD	TEST METHOD	ASTM
Color	D 1500	Polychlorinated Biphenyls (PCBs)	D 4059
Corrosive Sulfur	D 1275	Power Factor at 25°C	D 924
Dielectric Breakdown	D 877	Power Factor at 100°C	D 924
Dielectric Breakdown	D 1816	Relative Density 60/60	D 1298
Furanic Compounds	D 5837	Rotating Bomb	D 2112
Gassing Tendency at 80°C	D 2300	Viscosity at 40°C	D 445
Interfacial Tension	D 971	Visual Examination	D 1524
Neutralization Number	D 974	Water Content	D 1533
Oxidation Inhibitor Content	D 2668		

Qualification of a Refiner and Large Bulk Shipments of Oil

It is usually recommended that if a large quantity of new oil is to be purchased from a refiner during the course of year, the product (oil) from the refiner be qualified prior to initiation of shipments. Product qualification is usually accomplished by having the refiner submit samples for the tests referenced in Table 1. The purpose of the tests in Table 1 is to provide a comprehensive analysis of the oil to make certain that the oil meets certain minimum standards for electrical, physical and chemical properties. Once a product has been qualified it is absolutely necessary to confirm that a large shipment (tanker) of oil arrives uncontaminated. The tests in Table 2 are recommended tests that should be performed once tankers arrive on site prior to being placed into a transformer. It is assumed that the oil will be filtered (processed) in the transfer from the tanker to the transformer. In performing these tests, the test results from delivered oil should compare very closely to that of the qualification sample. It is well understood that some of these tests may take a day or more to complete and demurrage charges on the tanker(s) will be incurred. However, removal, flushing, and replacement of contaminated oil would be much more costly than the demurrage charges.

In certain cases, additional tests may be requested. For instance, analysis for benzotriazole (BTA), a metal deactivator in the oil, might be requested. This is especially true for those receiving transformers and oil internationally where the use of BTA is not prohibited.

TABLE 3

Tests on Small Shipments of New Oil (Tanker or Less)
Tests of New Oil Shipped in Large Power Transformers

TEST	ASTM METHOD	TYPE OF TEST
Dielectric Breakdown Voltage	D 877	Electrical
Dielectric Breakdown Voltage	D 1816	Electrical
Power Factor at 25°C	D 924	Electrical
Power Factor at 100°C	D 924	Electrical
Interfacial Tension	D 971	Physical
Relative Density 60/60	D 1298	Physical
Viscosity at 40°C	D 445	Physical
Color	D 1500	Physical
Visual Examination	D 1524	Physical
Oxidation Inhibitor Content	D 2668	Chemical
Water Content	D 1533	Chemical
Neutralization Number	D 974	Chemical
Polychlorinated Biphenyls	D 4059	Chemical
Furanic Compounds	D 5837	Chemical

TABLE 4

Tests for Oils Received in Drums and Small Distribution Transformers

TEST	ASTM METHOD	Perform on Drums	Perform on Transformers
Color	D 1500	Composite	YES
Dielectric Breakdown Voltage	D 877	YES	YES
Dielectric Breakdown Voltage	D 1816	NO	YES
Interfacial Tension	D 971	Composite	YES
Neutralization Number	D 974	Composite	YES
Oxidation Inhibitor Content	D 2668	Composite	YES
Polychlorinated Biphenyls	D 4059	Composite	YES
Power Factor at 25°C	D 924	Composite	YES
Power Factor at 100°C	D 924	Composite	YES
Relative Density 60/60	D 1298	Composite	YES
Visual Examination	D 1524	YES	YES
Water Content	D 1533	YES	YES

Small Shipments of New Oil and New Oil Shipped in Large Power Transformers

For small shipments of oil, a subset of the complete qualification tests such as those given in Table 3 can be used to check the quality of the oil. As long as there are no major discrepancies, there is reasonable assurance that the other oil properties should be acceptable. It should be noted that once oil has been placed in equipment it is no longer considered to have the same properties as oil in bulk containers, such as tankers, and is evaluated based on different limits.

As shown in Tables 1, 2, and 3 there is a requirement for analysis of polychlorinated biphenyls (PCBs). The analysis for PCBs needs to be performed only once during the life span of a transformer, as it is a characteristic that should not change. However, if after the test the oil is handled in a manner that might cause it to be contaminated with PCBs, then PCB analysis should be conducted again to verify the concentration for regulatory purposes. New oil should not have any PCBs present, but the methods and equipment used to transport and transfer the oil may result in accidental contamination and is very important that the concentration be measured prior to use.

Shipments of New Oil in Drums and Small Distribution Transformers

It is impractical to perform all the tests listed in Tables 2 or 3 on oil from drums. In some cases, tests should be made on a composite sample from five to 10 (or more) drums performing the tests listed as 'composite' in Table 3 to provide an indication of the overall quality of oil received. Tests on oil in small distribution transformers are usually not as critical as in power transformers.

Baseline Tests for Power and Distribution Transformers

In addition to the testing specified in Tables 3 and 4, there are certain tests that should be performed immediately after a transformer is placed in service or energized (if there will probably be a long duration before actually being placed into service). This is recommended in order to provide a baseline analysis to enable trending over the service life of a transformer and to assure that the transformer does not have any gross contamination present. These additional tests are indicated in Table 5.

TABLE 5
Tests after Energizing New Transformers

TEST	METHOD	Perform on Distribution Transformers	Perform on Large Power Transformers
Dissolved Gases in Oil	D 3612	YES	YES
Furanic Compounds in Oil	D 5837	YES	YES
Metals (Dissolved) in Oil	D 5185	NO	YES
Metals (Particulate) in Oil	Doble	NO	YES
Particle Count	Doble	NO	YES
Water Content and Relative Saturation	D 1533	YES	YES

TABLE 6
Tests for In-Service Oils in Transformers

TEST	ASTM METHOD	Perform on ≤ 69 kV Units	Perform on >69 kV ≤ 288 kV Units	Perform on >288 kV Units
Color	D 1500	YES	YES	YES
Dielectric Breakdown Voltage	D 877	YES	YES	NO
Dielectric Breakdown Voltage	D 1816	YES	YES	YES
Dissolved Gases in Oil	D 3612	YES	YES	YES
Furanic Compounds in Oil	D 5837	YES	YES	YES
Interfacial Tension	D 971	YES	YES	YES
Neutralization Number	D 974	YES	YES	YES
Oxidation Inhibitor Content	D 2668	YES	YES	YES
Particle Count	Doble	NO	YES/NO	YES
Pour Point	D 97	NO	YES/NO	YES
Power Factor at 25°C	D 924	YES	YES	YES
Power Factor at 100°C	D 924	YES/NO	YES	YES
Relative Density 60/60	D 1298	YES	YES	YES
Viscosity at 40°C	D 445	NO	YES/NO	YES
Visual Examination	D 1524	YES	YES	YES
Water Content and % Saturation	D 1533	YES	YES	YES

YES/NO indicates that it is a useful test to perform but it is not always necessary.

Tests to Perform on In-Service Oils

Since the oil and solid insulation deteriorates in a transformer while it is in service, periodic sampling and testing is necessary to ensure that deterioration is detected before it becomes excessive. The rate at which the insulating materials will degrade depends on several factors, such as the type of oil preservation system (amount of oxygen present), operating temperature, water content of the insulation, and the amounts and types of contaminants. The frequency at which testing is conducted varies with the test, importance of the equipment, whether an incipient-fault condition is known to be present or if a problem exists, and when a family of transformers has been identified as having a history of problems. All large power and large distribution transformers should be tested immediately after installation and periodically thereafter. Those units experiencing rapid deterioration of the oil or paper or those units for which an incipient-fault condition has been identified should be subjected to more frequent testing. Table 6 provides some guidance as to which tests to choose.

It has become common practice to group some of the tests listed in Table 6 into "screen packages" consisting of five to 10 tests which are routinely employed to check the condition of transformer oil. For example, physical tests such as visual examination/color and relative density are combined with electrical tests such as dielectric strength and power factor and also with chemical tests such as water content and neutralization number to form a screen package. Be advised that each laboratory has its own screen package tests and there is no standardization throughout the industry. Make sure the screen package that a laboratory is offering are the tests that are required. 

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